Kentucky

Agricultural Experiment Station

University of Kentucky

CALCIUM METABOLISM IN THE LAYING HEN
III
CALCIUM CARBONATE AND HATCHABILITY

BULLETIN NO. 291

(RESEARCH BULLETIN)

Lexington, Ky.

January, 1929

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SUMMARY

In the absence of a calcium carbonate supplement (limestone, oystershell) from the diet of laying hens on a ration consisting of yellow corn, wheat and buttermilk, fed *ad libitum* (with cabbage, lettuce or other green feed twice a week) the following results were observed, as compared with similar hens that received calcium carbonate (oystershell), under the same conditions:

1. The hatchability of fertilized eggs was diminished, finally becoming zero.
2. The percentage of infertile eggs was increased.
3. Fewer eggs were laid.
4. The eggs became smaller.
5. The shells became lighter.
6. The chicks hatched weighed less.
7. The ratio of the weight of the moisture-free carcass of the chick to the original weight of the contents of the egg from which it was hatched was less.

CONTENTS

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(RESEARCH BULLETIN)

Calcium Metabolism in the Laying Hen. III*

CALCIUM CARBONATE AND HATCHABILITY

By G. DAVIS BUCKNER, J. HOLMES MARTIN and A. M. PETER

The hatchability of eggs is of great importance to the poultryman. It is estimated that under ordinary conditions approximately 20 to 25 percent of fertile eggs incubated do not hatch and approximately 5 to 10 percent of the chicks hatched are weaklings that should be killed for economic reasons. Aside from its economic importance the question of hatchability is interesting from a scientific standpoint because of the many biologic relations involved. The object of this investigation was to determine whether low hatchability is caused in part by absence of calcium carbonate in the diet of the hens.

FACTORS WHICH AFFECT HATCHABILITY

The conditions generally considered most conducive to the production of eggs of low hatchability are close inbreeding and confinement, with restriction of green feed in winter and, possibly, the thinning of the shells which may accompany high egg production. It is also accepted as true that the hatchability of fertile eggs may be influenced by the age of the eggs at setting time and the temperature, humidity and turning during incubation.

Sanctuary (1) reports that one of the causes of "dead in the shell" chicks is a malposition of the embryo, such as head between the thighs. He found indications that malposition is an inherited characteristic and may be the result of lethal genes.

*Parts I and II were published as Bulletin No. 250 and Bulletin No. 252 of this Station.

He suggests, also, that the method of handling or turning the eggs may influence the position of the embryo in such a way as to affect hatchability.

Hughes, Payne and Latshaw (2) have reported very interesting experiments on the influence of ultraviolet light on hatchability. They state "The amount of sunshine preceding and during the time the egg is being produced is one of the factors determining its hatchability."

Dunn (3) has described experiments on the relation between the weight of eggs and the rate at which they lose water, as affecting hatchability, and concludes that "External characteristics of eggs do not appear to afford an approach to the chief clue we are seeking in the hatchability of eggs. All of our observations point rather to the interior than to the exterior of eggs as a focus of causes of embryonic death. . . ." In other words, it is indicated that the hatching qualities are not dependent on the size of the egg or the rate of evaporation as determined by porosity or thinness of shell.

Payne (4) has found that many of the embryos that die in the shell after the 14th day are deformed.

Kennard and White (5) have stated that they have increased the hatchability of the eggs from the Ohio Experiment Station flock from 30 or 40 percent to 60 or 70 percent by allowing the breeding stock to range upon rye or bluegrass pasture during the winter and eliminating close inbreeding.

Atwood (6) urges the liberal use of green feeds during winter confinement and the use of semisolid buttermilk, to raise the percentage of eggs that hatch.

Riddle (7) has published very interesting work concerning inadequate eggshells and the early death of embryos in the egg, in which he observed the hatchability of eggs laid under apparently normal conditions, by ringdoves on a normal diet, and determined the inadequacy of the shells by the rate of evaporation of moisture from the eggs. He concludes, among other things, that "The production of inadequate shells and the early death of the embryos are thus closely associated, altho the relative inadequacy of a particular shell is but loosely correlated with

the death of the particular embryo contained within it. An unknown and more deeply seated cause is responsible for both the occasional inadequate or irregular shells and the numerous early deaths of embryos.''

In another paper Riddle and Hanke (8) report on the effect of feeding calcium lactate and lactophosphate upon reproductive secretions of ringdoves and upon the total inorganic constituents of the eggshell. They conclude in part that ''The amount of inorganic substance laid down in the eggshell was practically unchanged by the extra calcium feeding.'' It is obvious that in these experiments Riddle and Hanke were dealing with pigeons whose tendency to lay eggs having thin or inadequate shells was not influenced by the addition of the calcium compounds mentioned, to the diet, and that this condition was peculiar to the birds in question. Either the calcium compounds used were not suitable for eggshell production or the production of thin shells was an inherited character. The authors finally conclude that ''The production of inadequate shells, or of thin-shelled eggs, which is associated with the early death of many bird embryos, is probably not caused by an inadequate calcium supply in the food.''

Calcium Supply and Hatchability

Buckner and Martin (9) have shown experimentally that calcium limitation in a ration for hens causes thin shells to be formed, but does not alter the percentage of calcium in the liquid portion of the eggs produced.

Delezenne and Fourneau (10) have shown that approximately 75 percent of the calcium of the mature chick embryo comes from the shell during the process of incubation.

What, then, is the comparative hatchability of eggs having normally thick shells, produced by hens receiving an abundance of calcium carbonate in their diet, and of those having thin shells, produced under calcium deficiency, by hens receiving no calcium carbonate, when all other factors are equal? It seems reasonable to believe that there must be a difference when we know that the normal dry eggshell of a standard White Leghorn

hen weighs 5.2 grams, as compared with 3.5 grams for the average shell from the same breed, on the same ration but without calcium carbonate.

The Experiments

The presentation and discussion of the experiments described herein, which extend over two successive years, is divided into two parts. Part 1 deals with the influence of calcium carbonate (oystershell) fed with a grain-buttermilk ration, on the hatchability of the eggs laid. Part 2 gives further evidence on this subject, including, also, the weights of the chicks hatched.

PART I—EXPERIMENTS IN 1923-24

Three lots of hens were used, each composed of 10 single-comb White Leghorns which came from the same parent stock and were the same age. These hens had been raised under identical conditions and each lot had an average trap-nest record of approximately 160 eggs per hen, for the pullet year. On November 1, 1923, each lot was put into a house 10×10 feet, the three houses being identical in construction and orientation. Unglazed windows on the south side admitted sunlight equally to the houses. Lot 1 was allowed daily freedom of an enclosure about 30 by 60 feet, covered with bluegrass sod, while lots 2 and 3 were kept in their houses thruout the experiment. All three lots were fed the same ration consisting of yellow corn and wheat with buttermilk always before them, and cabbage, lettuce or other greens fed twice a week. During the first six months, lots 1 and 2 received oustershell *ad libitum* while lot 3 received no calcium supplement. Siliceous grit which had been freed of calcium carbonate or other soluble calcium compound by washing with hydochloric acid and water, was supplied to lots 2 and 3 at the rate of 20 grams per month, per hen, while lot 1 received it *ad libitum*. The oat-straw litter was changed when necessary. Three cocks of the same age, coming from the same parent stock as the hens, as nearly alike as possible, whose fertilizing powers were known to be high, were placed in the pens, one in each.

Starting March 1, 1924, after the hens had been under these conditions for 4 months, the eggs were collected in 14-day periods, for incubation. At this time the average dry weights of the eggshells, including the membranes, were 5.5, 5.7 and 4.1 grams, for lots 1, 2 and 3, respectively, computed from the eggs laid during February.

The eggs were candled for soundness of shell, placed in an incubator and on the 18th day examined for fertility and dead germs. Sufficient time was allowed after the 21st day for those late in hatching, and those remaining unhatched were classed as dead in the shell. The results are shown in the first three columns of Table 1, the percentages being stated in the nearest whole numbers, computed upon the total number of eggs set each time.

Always more eggs were laid in lot 1 than in the other lots, presumably owing to the freedom of the grass range. As in previous experiments,* the hens receiving calcium carbonate (oystershell) laid more eggs than those receiving no calcium supplement (see Table 4).

On May 1 oystershell was added to the ration of lot 3 and withheld from lots 1 and 2, all other conditions remaining unchanged. Three settings were then made, on May 12, May 27 and June 10, the results of which are given in the last three columns of Table 1, computed as percentages of the number of eggs set.

After these changes, the number of eggs laid by lots 1 and 2 decreased decidedly, and the number laid by lot 3 increased distinctly, showing the influence of the calcium carbonate supplement.

The hatchability of the eggs from lot 1 is nearly the same for the first two settings, with an unaccountable fall in the third. In lot 2 the hatchability unaccountably rises in the third hatch, while in lot 3 which received no calcium supplement the hatchability decreased from 21 percent in the first hatch to 18 percent in the second and zero in the third. In lot 3 the largest percentage of deaths of embryos occurred from the 18th

*Kentucky Agricultural Experiment Station, Bulletins Nos. 250 and 252, of this Station.

to the 21st day, in the first and second hatches, but in the third hatch the largest percentage was prior to the 18th day the deaths occurring earlier, under these conditions. The percentage of infertile eggs increased with lapse of time in lot 3, diminished in lot 2 and was fairly uniform in lot 1.

TABLE 1. Hatchability of eggs from Hens With and Without Calcium Carbonate in Their Diet. Stated as Percentage of all the Eggs in Each Setting.

HATCH NUMBER	1	2	3	4	5	6
Date of Setting, 1924	Mch. 14	Mch. 28	Apr. 11	May 12	May 27	June 10
Lot 1. Range	With Oystershell			Without Oystershell		
Percentage hatched	66	64	44	22	18	42
Percentage dead in shell	16	12	24	37	66	30
Percentage dead germs, 18th day	8	12	18	22	9	21
Percentage infertile	10	12	14	19	7	7
Number of eggs set	76	58	78	46	44	43
Lot 2. Confined	With Oystershell			Without Oystershell		
Percentage hatched	40	36	58	11	15	5
Percentage dead in shell	28	36	22	27	33	23
Percentage dead germs, 18th day	16	21	20	24	18	36
Percentage infertile	16	7	0	38	33	36
Number of eggs set	69	42	59	37	33	22
Lot 3. Confined	Without Oystershell			With Oystershell		
Percentage hatched	21	18	0	21	33	36
Percentage dead in shell	42	41	22	38	45	42
Percentage dead germs, 18th day	32	29	61	21	12	11
Percentage infertile	5	12	17	20	10	11
Number of eggs set	19	17	18	29	40	36

The decrease in the percentage of chicks hatched, following exclusion of oystershell, is particularly noticeable in lot 2, which did not have range. While hatchability decreased markedly in lot 1, at first, the third hatch shows recovery, possibly because the hens gleaned some calcium carrier from the range. On the other hand, the increase in hatchability of the eggs in lot 3 which now received calcium carbonate is decided and continued

and the larger percentage of deaths of embryos occurred subsequently to the 18th day. Withholding calcium carbonate from lot 1 seems to have caused a temporary decrease in the fertility of the eggs and there is a marked decrease in the fertility of the eggs of lot 2 following the withholding of calcium carbonate.

In Table 2 the percentages have been computed upon the number of fertile eggs in each incubation.

TABLE 2. Hatchability of Fertile Eggs from Hens With and Without Calcium Carbonate in Their Diet. Stated as Percentage of the Fertile Eggs in Each Setting.

HATCH NUMBER	1	2	3	4	5	6
Date of setting, 1924	Mch. 14	Mch. 28	Apr. 11	May 12	May 27	June 10
Lot 1. Range	With Oystershell			Without Oystershell		
Percentage hatched	73	72	51	27	19	45
Percentage dead in shell	18	14	28	46	71	33
Percentage dead germs, 18th day	9	14	21	27	10	22
Number of fertile eggs	68	51	67	37	41	40
Lot 2. Confined	With Oystershell			Without Oystershell		
Percentage hatched	48	38	58	17	23	7
Percentage dead in shell	33	39	22	44	50	36
Percentage dead germs, 18th day	19	23	20	39	27	57
Number of fertile eggs	58	39	59	23	22	14
Lot 3. Confined	Without Oystershell			With Oystershell		
Percentage hatched	22	20	0	26	36	41
Percentage dead in shell	45	47	27	48	50	47
Percentage dead germs, 18th day	33	33	73	26	14	12
Number of fertile eggs set	18	15	15	23	36	32

In the foregoing experiment it appears that the hatchability of the eggs was markedly diminished in the absence of an adequate supply of calcium carbonate from the diet of the hens. In what way this deleterious action is produced we cannot say. The possibility of any factor other than the lack of calcium effecting these results seems to be excluded because of the reversal when the calcium supplement was added or withheld.

Certainly, a deficiency of calcium carbonate resulted in the production of lighter shells, possibly permitting increased evaporation of water, which might have a deleterious effect, tho the findings in the second experiment (see p. 19) do not indicate a material difference in the rate of evaporation. It seems probable, therefore, that some important metabolic process in the hen is interfered with by the lack of calcium carbonate.

Table 3 gives the monthly egg record for the three lots. Egg production was increased greatly by the addition of calcium carbonate to the diet.

TABLE 3. Monthly Egg Production. 1923-1924.

MONTH	Nov.	Dec.	Jan.	Feb.	Mch.	Apr.	Av. Feb. Mch. & Apr.	May	June	July	Av. May June & July
Lot 1. Range	With Oystershell						Without Oystershell				
Number of hens	9	9	9	9	9	9		8.3	8	8	
Total eggs	68	136	98	99	187	194		183	130	148	
Eggs per hen	7.4	15.1	10.9	11.0	20.1	21.6	18.7	22.3	16.3	18.5	19.0
Lot 2. Confined	With Oystershell						Without Oystershell				
Number of hens	9	9	9	9	9	9		9	8.7	8	
Total eggs	45	120	112	129	155	160		145	47	43	
Eggs per hen	5.0	13.3	12.4	14.3	17.2	17.7	16.4	16.1	5.4	5.4	9.1
Lot 3. Confined	Without Oystershell						With Oystershell				
Number of hens	10	10	10	10	9	9		9	9	9	
Total eggs	48	40	36	43	56	68		170	169	148	
Egg per hen	4.8	4.0	3.6	4.3	6.2	7.6	6.0	18.9	18.8	16.4	18.0

Table 4 gives the monthly average weight of one egg, the dry shell with membrane, and the contents by difference. As in the previous experiments cited, the eggs were smaller and the shells lighter in the absence of oystershell than they were when oystershell was given to the hens. In lot 3, however, tho the weight of shell was increased materially after the addition of oystershell to the diet, the weight of the contents was not increased.

TABLE 4. Monthly Average Weights in Grams of One Egg, Shell with Membrane, and Contents. 1923-1924.

MONTH	Nov.	Dec.	Jan.	Feb.	Mch.	Apr.	Av. Feb. Mch. & Apr.	May	June	July	Av. May June & July
Lot 1. Range	With Oystershell							Without Oystershell			
Egg	60.4	57.5	58.3	60.1	58.9	57.1	58.5	54.4	50.8	52.5	52.8
Dry shell and membrane	5.7	5.5	5.3	5.5	5.2	4.9	5.1	4.7	4.5	4.2	4.5
Contents, by difference	54.7	52.0	53.0	54.6	53.7	52.2	53.4	49.7	46.3	48.3	48.3
Lot 2. Confined	With Oystershell							Without Oystershell			
Egg	56.0	59.1	59.4	60.0	58.4	56.2	57.9	52.6	49.7	51.5	51.8
Dry shell and membrane	5.5	5.7	5.8	5.7	5.4	5.2	5.0	4.3	3.8	4.0	4.1
Contents, by difference	50.5	53.4	53.6	54.3	53.0	51.0	52.9	48.3	45.9	47.5	47.7
Lot 3. Confined	Without Oystershell							With Oystershell			
Egg	54.8	54.8	55.3	53.0	54.5	54.2	54.0	55.1	54.0	53.3	54.2
Dry shell and membrane	5.0	4.1	4.2	4.1	3.5	3.8	3.9	5.2	5.0	5.1	5.1
Contents, by difference	49.8	50.7	51.1	48.9	51.0	50.4	50.1	49.9	49.0	48.2	49.1

PART II—EXPERIMENTS IN 1924-25

The results of the experiment described in Part I were so striking and of such importance that it was deemed advisable to verify them on a more comprehensive scale; accordingly, the following experiment was undertaken.

Three lots of hens were used, designated as lots 4, 5 and 6, each containing 10 single-comb, White Leghorns, all from the same parent stock, of the same age, having been hatched in the same incubator on April 20, 1923, and raised under identical conditions. Hens of nearly equal egg-laying records were selected, so that the trap-nest records for their pullet year averaged 155, 159 and 157 eggs per hen for the three lots, respectively. In making the division the weights of the hens, also, were equalized as nearly as possible. These averaged 1716

1699 and 1667 grams per hen, for the three lots, respectively, on January 1, 1925, the date when the experiment began.

On this day the three lots were put into the same houses that had been used in the first experiment (Part I, p. 8). Lot 4 was allowed daily freedom of the same bluegrass range which had been used for lot 1, while lots 5 and 6 were kept in their houses thruout the experiment. All three lots were fed, *ad libitum,* the same ration of yellow corn, wheat and buttermilk, supplemented with cabbage, lettuce or other green food twice a week, as in the first experiment. Lots 4 and 5 received crushed oystershell, *ad libitum,* while it was withheld from lot 6. Siliceous gravel which had been freed from soluble calcium compounds by washing with dilute hydrochloric acid and water, was supplied at the rate of 20 grams per hen, per month. The oat straw litter was changed frequently. A cock of known high fertilizing power, of the same age as the hens and from the same parent stock, was put into each house. The cocks were rotated each week from house to house.

Starting March 4, after the hens had been about 9 weeks under the conditions described, the eggs were collected for incubation. The average weights of the dry eggshells at this time were 6.3, 6.0 and 4.2 grams, respectively, for lots 4, 5 and 6, determined from the eggs laid on the last day of February. Settings were made March 14, April 11, May 4, June 20, July 1, and July 14, using the eggs collected during the 10-day period immediately preceding the dates of setting. Because the hens in lot 3 had practically stopped laying and several hens in each lot were broody and moulting, no incubations were made after July 14.

The eggs were allowed to incubate in an electrically heated incubator until the 18th day, when they were candled and the infertile and dead-germ eggs removed; the remaining eggs were sacked and the incubation was completed. The eggs that hatched were counted and those remaining were noted as "dead in the shell." The "dead-in-the-shell" chicks were examined but none were found to be in malposition as described by Sanctuary as being a cause of failure of the chicks to emerge from the shell.

In fact, the position of the chick in the shell was normal in every instance and in 74 percent of these eggs the shells had been pipped by the chick. No deformed chicks were found.

In order to observe the relation between weight and hatchability of eggs of the individual hens, the eggs for settings Nos 1 and 2 were weighed separately the day laid and the average weight obtained therefrom. The findings are stated in Tables 11, 12 and 13, together with the record of hatchability.

On the 18th day the infertile and "dead-in-the-shell" eggs were weighed.

In Table 5 is given the average percentage of eggs that hatched, together with the percentage of "dead-in-the-shell,"

TABLE 5. Hatchability of Eggs from Hens With and Without Calcium Carbonate in Their Diet. Stated as Percentages of all the Eggs in Each Setting.

HATCH NUMBER	1	2	3	4	5	6	
Date of setting. 1925	Mch. 14	Apr. 11	May 4	Juné 20	July 1	July 13	Ave.
Lot. 4. Range with oystershell							
Percentage hatched	59	41	35	79	35	50	48
Percentage dead in shell	26	27	28	4	29	28	24
Percentage dead germs, 18th day	3	15	19	4	27	11	13
Percentage infertile	12	17	18	13	9	11	15
Number of eggs set	58	73	120	52	34	36	373*
Lot 5. Confined. With oystershell							
Percentage hatched	67	39	33	64	26	19	42
Percentage dead in shell	20	24	29	18	35	23	25
Percentage dead germs, 18th day	5	22	11	12	17	27	14
Percentage infertile	8	15	27	6	22	31	19
Number of eggs set	60	75	111	33	23	26	328*
Lot 6. Confined. Without oystershell							
Percentage hatched	57	35	26	17	0	0	32
Percentage dead in shell	9	15	24	41	67	33	24
Percentage dead germs, 18th day	17	23	17	17	11	45	19
Percentage infertile	17	27	33	25	22	22	25
Number of eggs set	42	40	42	24	9	9	166*

*Total eggs in the 6 settings.

dead germ and infertile eggs, for each incubation, calculated on the total number of eggs set. In Table 6, the percentages have been calculated upon the number of fertile eggs found in each incubation.

TABLE 6. Hatchability of Eggs from Hens With and Without Calcium Carbonate in Their Diet. Stated as Percentage of the Fertile Eggs in Each Setting.

HATCH NUMBER	1	2	3	4	5	6	
Date of setting	Mch. 14	Apr. 11	May 4	June 20	July 1	July 13	Ave.
Lot. 4. Range with oystershell							
Percentage hatched	67	49	43	91	39	56	56
Percentage dead in shell	29	33	33	5	32	31	28
Percentage dead germs, 18th day	4	18	24	4	29	13	16
Number of fertile eggs set	51	61	98	45	31	32	318*
Lot 5. Confined. With oystershell							
Percentage hatched	73	45	46	68	33	28	52
Percentage dead in shell	22	28	39	19	45	33	31
Percentage dead germs, 18th day	5	27	15	13	22	39	17
Number of fertile eggs set	55	64	81	31	18	18	267*
Lot 6. Confined. Without oystershell							
Percentage hatched	69	48	39	22	0	0	43
Percentage dead in shell	11	21	36	56	86	43	31
Percentage dead germs, 18th day	20	31	25	22	14	57	26
Number of fertile eggs set	35	29	28	18	7	7	124*

*Fertile eggs in the 6 settings.

The figures in Tables 5 and 6 show that the hatchability of the eggs laid by the hens that received no calcium carbonate decreased steadily from 57 percent in March to zero in July, the nine eggs set July 1 and the nine set July 13 having failed to hatch. The hatchability of the eggs from the two lots that received calcium carbonate, tho varying greatly and much less in July than in March, was still considerable in the last incubation.

The hatchability of the eggs from the hens that received no calcium carbonate was always distinctly less than that of the eggs from the hens that received it. This confirms the result of the first experiment and shows that, under the conditions of this experiment, a grain-buttermilk diet with some green feed was not adequate, but the addition of calcium carbonate to this diet contributed materially to the maintenance of hatchability Hatchability was appreciably greater in lot 4 than in lot 5, showing that range for the hens contributed materially to the maintenance of hatchability.

The average monthly egg production per hen increased steadily in all the lots to a maximum in April. The percentage of infertile eggs found in the first three incubations increased similarly and the hatchability of the fertile eggs decreased. Egg production fell off in May, most decidedly in lot 4, and hatchability increased strikingly in the fourth hatch (May 20) in the two lots receiving calcium carbonate, but continued to decrease in lot 6. These observations suggest the influence of egg production on hatchability and fertility. In lot 6 this influence, apparently, was dominated by the lack of calcium carbonate.

DRY WEIGHT OF THE CHICK

After all the chicks had hatched, they were chloroformed and dried to constant weight at 100° C. From these weights the averages given in Table 5 were obtained.

The findings in Table 7 show that the solid substance of the chick hatched from an egg of a hen receiving no calcium carbonate weighed less than that of the corresponding chick from the hen that received calcium carbonate; also, it represented a smaller percentage of the weight of the original egg. A comparison with the weight of the egg contents, if it could be made, would show a still more striking difference, because the weight of the shell must have been considerably less in the eggs of lot 6 than in those of the other lots. Apparently the absence of calcium carbonate from the diet of the mother hen brings about conditions inimical to the proper development of the embryo

TABLE 7. Average Weights in Grams of the Eggs Set and of the Dried Carcasses of the Chicks Hatched in the Six Incubations and the Percentage that the Weight of the Dried Carcass is of the Weight of the Original Egg.

HATCH NUMBER	1	2	3	4	5	6
Date of setting. 1925	Mch. 14	Apr. 11	May 4	June 20	July 1	July 13
Lot. 4. Range, with oystershell						
Egg	60.2	59.4	59.0	59.2	59.0	58.0
Dry carcass	11.0	10.7	11.0	10.8	10.9	10.5
Percent	18.3	18.0	18.6	18.2	18.5	18.1
Lot 5. Confined, with oystershell						
Egg	59.3	60.0	58.9	58.3	59.1	57.6
Dry carcass	10.5	9.5	10.3	10.0	9.8	10.0
Percent	17.7	15.8	17.5	17.2	16.6	17.4
Lot 6. Confined, without oystershell						
Egg	56.0	55.4	55.0	53.3	54.0	52.9
Dry carcass	10.0	8.8	8.0	7.9	.....	.....
Percent	17.9	15.9	14.5	14.8	.....	.....

and chick in the egg, as evidenced by the facts just mentioned and by the loss of hatchability previously shown. The percentage of the dried carcass is distinctly less in lot 5 than in lot 4, and less uniform, suggesting beneficial influence of free range.

LOSS OF WEIGHT OF EGGS BY EVAPORATION

The infertile eggs removed from the incubator on the 18th day in the first hatch, were weighed and the loss in weight determined. The results are stated in Table 8.

The percentage of loss in weight is fairly uniform for the three lots, indicating that the character of the shells of the eggs in lot 6 was not such as to cause increased evaporation, tho presumably they were the thinnest.

TABLE 8. Loss by Evaporation in 18 Days Incubation.

	Lot 4 Oyster-shell Range	Lot 5 Oyster-shell Confined	Lot 6 No Shell Confined
Number of infertile eggs	7	8	3
Av. wt. when set, grams	61.5	61.6	55.6
Av. wt. on 18th day, grams	54.7	53.5	49.3
Av. loss in weight, grams per egg	6.8	8.1	6.3
Percentage loss	11.5	13.1	11.3

The loss of weight of the eggs containing dead germs, taken from the incubator on the 18th day, was determined in a similar way. The results are stated in Table 9.

TABLE 9. Loss of Weight of "Dead Germ" Eggs in 18 Days.

	Lot 4 Oyster-shell Range	Lot 5 Oyster-shell Confined	Lot 6 No Shell Confined
Number of "dead germ" eggs	2	2	6
Av. wt. when set, grams	66.5	65.7	53.8
Av. wt. on 18th day, grams	57.8	55.8	40.1
Av. loss in weight, grams per egg	8.7	9.9	13.7
Percentage loss	13.1	15.1	25.5

Presumably the development of the chick was more advanced in some of these eggs than in others, and the loss in weight was due only partly to evaporation of water. Therefore the greater loss in the eggs of lot 3 does not necessarily indicate increased evaporation of water permitted by thinner shells. It suggests, rather, that these chicks were farther developed than the others.

WEIGHT OF THE EGG AND HATCHABILITY

Each egg collected for hatches 1 and 2 was weighed separately the day it was laid. From these weights the averages in Table 10 have been computed for the two incubations taken together.

Not more than half the eggs that hatched were above the average in weight, and in lot 4, only about 40 percent were over

TABLE 10. Average Weight and Hatchability in the First Two Incubations, Set March 14 and April 11, 1925.

	Lot 4 Range Oyster-shell	Lot 5 Confined Oyster-shell	Lot 6 Confined Without Oyster-shell
Number of eggs hatched	64	68	48
Average weight, grams	58.9	61.1	54.9
Number of these above the av. wt.	26	31	24
Their average weight, grams	62.6	61.4	57.4
Number dead in the shell	35	31	13
Average weight, grams	59.8	61.4	56.4
Number dead germs on 18th day	13	20	16
Average weight, grams	62.2	58.4	54.5
Number infertile	18	15	12
Average weight, grams	59.2	62.1	54.6
Total number of eggs	130	134	89
Average weight, grams	59.5	60.8	55.0
Percentage hatched	49.2	50.8	53.9

the average. The figures seem to indicate that the smaller eggs have a relatively greater hatchability, as observed by Dunn(11).

Tables 11, 12 and 13 give the hatchability record and average weight of the eggs from each hen, for the first two incubations.

TABLE 11. Hatchability Record and Average Weight of Eggs of Individual Hens of Lot 4. Oystershell and Range.

	Hatch No. 1—March 14, 1925						Hatch No. 2—April 11, 1925					
Hen Number	No. of eggs set	Av. wt. of 1 egg, gms.	No. of infertile eggs	No. of dead germs	No. dead in shell	No. hatched	No. of eggs set	Av. wt. of 1 egg	No. of infertile eggs	No. of dead germs	No. dead in shell	No. hatched
8	5	59.6	0	0	3	2	11	56.0	0	1	3	7
10	8	60.3	0	0	2	6	11	57.0	0	2	4	5
18	6	59.1	3	0	0	3	8	57.6	8	0	0	0
64	5	58.9	0	0	0	5	11	57.5	0	0	4	7
145	8	63.0	2	0	6	0	11	62.4	3	1	4	3
146	1	58.4	0	0	0	1	6	56.8	1	1	4	0
150	9	56.9	1	0	2	6	4	55.8	0	0	0	4
164	9	62.0	0	1	0	8	6	59.0	0	2	0	4
215	7	67.4	1	1	2	3	5	65.0	0	4	1	0
238	0	*										
Total	58	59.9	7	2	15	34	73	58.5	12	11	20	30
Percent			12	3	26	59			17	15	27	41

*Dead Feb. 2, 1925. Cause unknown.

TABLE 12. Hatchability Record and Average Weight of Eggs of Individual Hens of Lot 5. Oystershell, No Range.

Hen Number	Hatch No. 1—March 14, 1925						Hatch No. 2—April 11, 1925					
	No. of eggs set	Av. wt. of 1 egg	No. of infertile eggs	No. of dead germs	No. dead in shell	No. hatched	No. of eggs set	Av. wt. of 1 egg	No. of infertile eggs	No. of dead germs	No. dead in shell	No. hatched
22	5	60.2	0	0	0	5	9	58.1	1	1	2	5
29	7	59.5	0	0	1	6	10	56.9	0	5	3	2
30	0	0	0	0	0	0	5	51.7	0	5	0	0
47	10	63.9	0	0	4	6	10	60.5	0	1	5	4
65	7	64.4	0	1	1	5	8	63.0	0	2	4	2
102	6	66.0	3	0	0	3	8	64.0	5	1	0	2
108	4	51.7	1	0	0	3	3	51.6	2	0	1	0
110	7	59.4	0	0	4	3	10	57.5	1	0	1	8
140	5	61.1	0	0	2	3	6	58.4	1	2	0	3
247	9	68.9	1	2	0	6	6	68.5	1	0	2	3
Total	60	62.6	5	3	12	40	75	59.5	11	17	18	29
Percent			8	5	20	67			15	22	24	39

TABLE 13. Hatchability Record and Average Weight of Eggs of Individual Hens of Lot 6. Neither Oystershell nor Range.

Hen Number	Hatch No. 1—March 14, 1925						Hatch No. 2—April 11, 1925					
	No. of eggs set	Av. wt. of 1 egg	No. of infertile eggs	No. of dead germs	No. dead in shell	No. hatched	No. of eggs set	Av. wt. of 1 egg	No. of infertile eggs	No. of dead germs	No. dead in shell	No. hatched
6	5	57.3	1	0	1	3	5	56.6	3	0	2	0
7	6	55.9	1	1	0	4	4	52.4	0	2	1	1
11	1	65.1	0	1	0	0	2	62.4	1	0	0	1
20	6	59.1	2	0	2	2	4	60.2	0	4	0	0
21	3	55.0	0	0	1	2	4	52.8	0	1	1	2
27	4	53.7	0	0	0	4	5	54.2	1	1	0	3
34	4	56.9	3	0	0	1	3	53.9	3	0	0	0
104	4	53.6	0	0	0	4	5	52.4	0	0	0	5
125	4	53.9	0	1	0	3	4	55.6	0	1	2	1
127	5	51.5	0	4	0	1	4	50.1	3	0	0	1
Total	42	55.6	7	7	4	24	40	54.6	11	9	6	14
Percent			17	17	9	57			27	23	15	35

The individual records of the first two incubations show that one or more hens in each lot laid eggs of low hatchability, but this does not seem to be associated with the average weight of their eggs.

CHANGE IN WEIGHT OF EGG IN THE PRELIMINARY PERIOD

As an index of the change taking place in weights of the shell and contents of the eggs laid by the hens of lot 6 before collection for incubation began, each egg laid by hen No. 7, before February 10, was weighed the same day laid, after which the shell was removed, with the membrane, and dried to constant weight at 100° C. The difference between the weight of an egg and the weight of its dry shell and membrane was taken as the weight of the contents. The results are given in Table 14. Six eggs were laid in the first 14 days, but only 4 in the last 26 days of the period, showing a marked decrease in egg production. The weight of shell, the weight of contents and the proportion of shell to contents decreased strikingly during the 40-day period.

TABLE 14. Individual Weights in Grams of Egg, Dry Shell and Membrane, and Contents. Hen 7, Lot 6, Jan. 1 to Feb. 15, 1925.

When Laid	Whole Egg	Shell and Membrane	Contents	Parts Shell to 100 Contents
Jan. 2	52.5	5.9	46.6	12.7
Jan. 5	52.1	5.4	46.7	11.6
Jan. 6	49.8	5.6	44.2	12.7
Jan. 9	50.2	5.2	45.0	11.6
Jan. 10	48.1	5.5	42.6	12.9
Jan. 14	51.1	4.8	46.3	10.4
Jan. 29	46.5	4.1	42.4	9.7
Jan. 30	47.1	4.3	42.8	10.0
Feb. 4	47.2	4.1	43.1	9.5
Feb. 9	47.0	3.9	43.1	9.0
Average 1st 6 eggs	50.6	5.4	45.2	11.9
Average last 4 eggs	46.9	4.1	42.8	9.6

CONCLUSION

The results of this investigation show that, under the conditions of this experiment, the addition of calcium carbonate to the diet of the hens is essential to the maintenance of hatchability

of their eggs. While the absence of calcium carbonate from the diet is accompanied by marked decrease in the weight of the egg shell, this circumstance does not appear to be connected with the loss of hatchability. The cause seems to be deeper seated and probably should be sought in connection with the metabolism of the mother hen.

From the practical standpoint, the investigation shows the importance of keeping the breeding flock well supplied with calcium carbonate in suitable form, such as oystershell, high-grade limestone or calcite, even when the birds are permitted to range.

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